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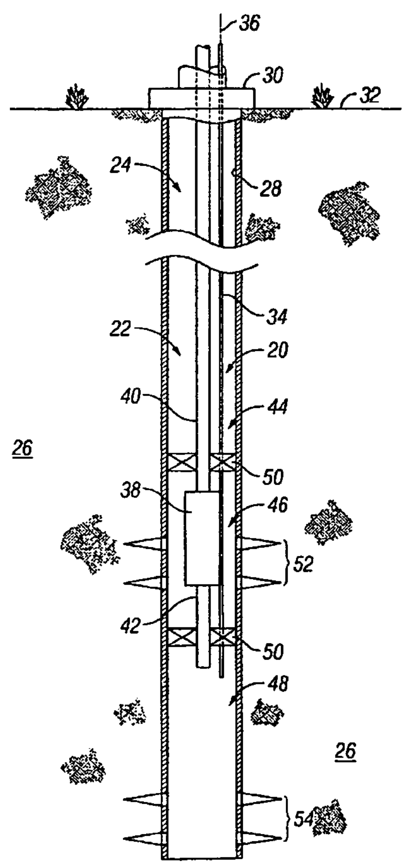
(54) Title: SENSOR ISOLATION SYSTEM FOR USE IN A SUBTERRANEAN ENVIRONMENT



(57) Abstract: A system for sensing desired parameters in a subterranean environment. The system utilizes a tube (34) having an internal communication line (36), such as an optical fiber (64), that is coupled to a selected sensor (66) or sensors along or within the tube. The tube is separated into one or more zones (88) that isolate desired regions around the sensor or sensors.

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U.S. Patent Application For

SENSOR ISOLATION SYSTEM FOR USE IN A SUBTERRANEAN ENVIRONMENT

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SENSOR ISOLATION SYSTEM FOR USE IN A SUBTERRANEAN ENVIRONMENT

FIELD OF THE INVENTION

The present invention relates generally to a technique for determining various parameters in a subterranean, e.g. wellbore, environment, and particularly to a technique for isolating regions in which the subject parameter or parameters are sensed.

BACKGROUND OF THE INVENTION

In many subterranean applications, it is desirable to sense various parameters. For example, in the production of gas and/or oil, wellbores are sometimes drilled into the earth to permit retrieval of the desired fluids. At various points of the drilling and production process, it may be desirable to determine certain parameters related to the formation and produced fluid.

A number of sensors, instruments, and techniques are used to determine the parameters of interest. In one such technique, temperature along the wellbore is sensed with a distributed temperature sensing system. One type of system uses a Raman scattering technique inside a multimode or single mode fiber that can be pumped downhole. The distributed temperature sensing system provides an efficient

method of determining temperatures at various locations along the wellbore. However, this technique has not been amenable for use with other types of sensors or mixtures of sensor types, particularly when accurate determination of the subject parameters requires isolation between zones along the formation, e.g. along the wellbore.

SUMMARY OF THE INVENTION

The present invention relates to a sensor system for use in subterranean environments, such as a wellbore environment associated with the production or injection of desired fluids. The technique utilizes a tubing that extends to the desired subterranean location. In an exemplary embodiment, the tubing is deployed within or along a wellbore. A communication line, e.g., one or more optical fibers, is disposed within the tubing for communication with a corresponding sensor or sensors deployed in one or more zones along the tubing. The sensor(s) may be permitted to communicate with the environment surrounding the tubing, and the tubing is segregated or isolated into zones around the sensor(s).

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements, and:

Figure 1 is a front elevational view of an exemplary system disposed within a wellbore, according to one embodiment of the present invention;

Figure 2 is a front elevational view similar to Figure 1 but illustrating an alternate embodiment;

Figure 3 is a schematic illustration of one embodiment of a zone isolation system;

Figure 4 is a schematic illustration of an alternate embodiment of a mechanism for isolating a zone;

Figure 5 is a front elevational view of an alternate embodiment of the zone isolation system illustrated in Figure 3;

Figure 6 is a schematic illustration of the sensor system of Figure 5 in an open configuration;

Figure 7 is a schematic illustration of the sensor system of Figure 5 in a closed configuration;

Figure 8 is a front elevational view of another embodiment of a sensor system isolated in a desired zone;

Figure 9 is a cutaway view of the sensor system illustrated in Figure 8;

Figure 10 is an expanded view taken from the region encircled by line 10-10 in Figure 9; and

Figure 11 is a front elevational view of another embodiment of a packer combined with isolation mechanisms.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

In the following, a technique for sensing a variety of parameters in a subterranean environment is described. The technique is described in exemplary environments and with exemplary embodiments, but those descriptions should not be construed as limiting. For example, the technique is illustrated in or along wellbores used in the production of desired fluids, such as petroleum and gas products, or injection of desired fluids, such as steam, water, or stimulants. However, the technique can be utilized in other applications and environments.

Referring generally to Figure 1, a sensor system 20 is illustrated in combination with a downhole completion system 22. In this embodiment, sensor system 20 and downhole completion system 22 are deployed in a wellbore 24 disposed in a subterranean formation 26.. Wellbore 24 may be lined with a wellbore casing 28 extending into subterranean formation 26 from a wellhead 30 disposed along a surface 32 of the earth.

In the embodiment of Figure 1, sensor system 20 comprises a tube 34 extending into wellbore 24. Although the material, construction and size of tube 34 may vary depending on the application, an exemplary tube 34 is a stainless steel tube. The exemplary tube has a diameter less than approximately one half inch and often is approximately one quarter inch.

A communication line 36 is disposed in the interior tube 34 and may comprise electrical conductors and/or one or more optical fibers. The communication line, e.g. optical fibers or electrical cable conductors, can be deployed within tube 34 by, for example, pumping the fibers along the interior of the tube with the use of fluid drag. During or prior to installation of line 36 in tube 34, downhole

sensors are coupled to the communication line, as described more fully below.

With respect to downhole completion system 22, a variety of completions 38 may be utilized in numerous arrangements and applications. The illustrated downhole completion system 22 is merely an example and representative of the numerous systems that may be employed in a given environment and application. In this embodiment, completion 38 is coupled to a primary tubing 40 that typically has a diameter substantially greater than that of tube 34. Exemplary primary tubing 40 comprises production tubing through which a fluid, such as oil, is produced from completion 38. For example, completion 38 may comprise a pumping system, e.g. an electric submersible pumping system, that produces the desired fluid to wellhead 30. Completion 38 or additional completions also can be used to perform a variety of other functions, such as the injection of separated water into other wellbore zones through appropriate discharge tubing 42.

In the illustrated example as well as a variety of other applications, it is beneficial to divide wellbore 24 into zones, such as zones 44, 46 and 48. One or more packers 50 can be used to establish the separate wellbore

zones. In the illustrated embodiment, for example, two packers 50 are used to divide wellbore 24 into three zones 44, 46 and 48. Openings, e.g., perforations 52 and 54, are formed through wellbore casing 28 in at least one of the zones, such as zone 46 and zone 48, respectively. Perforations 52 and 54 permit communication of fluids between subterranean formation 26 and the interior of wellbore casing 28.

In many types of applications, it is desirable to sense various parameters (physical or chemical properties, such as pressure, flow, strain, chemical property, temperature, distributed temperature, acoustic energy, electric current, or magnetic field) at one or more zones along wellbore 24, e.g. zones 44, 46 and/or 48. However, if the sensor is located within tube 34, the subject parameter may be sensed inaccurately, unless the desired zone also is isolated in tube 34. For example, when sensing distributed or multiplexed pressure, the pressure between stations or zones should be isolated from the hydrostatic pressure of fluid inside the tube 34 and from the pressure from the other zones. Accordingly, sensor system 20 incorporates a variety of isolation mechanisms, as described with reference to Figures 3 through 10. The mechanisms permit the isolation

of zones within tube 34. Often, the isolated zones are correlated with zones 44, 46 and 48.

It should be noted that in the embodiment illustrated in Figure 1, tube 34 and communication line 36 are deployed within wellbore casing 28 generally along primary tubing 40. In this embodiment, tube 34 extends through the one or more packers 50. Alternatively, however, tube 34 can be deployed in or external to wellbore casing 28, as illustrated best in Figure 2.

Referring generally to Figure 3, an exemplary technique for isolating a zone of tubing 34 is illustrated. In this embodiment, the zone isolated within tube 34 corresponds generally to the external zone isolated between packers 50, such as zone 46 of Figure 1. An isolated tube zone 56 is created between a pair of isolation mechanisms 58 disposed within tube 34. Generally, isolation mechanism 58 can be activated to compress one or more communication lines 36 (such as optical fibers 64) and thereby provide seal thereacross. Isolation mechanisms 58 may also be constructed to be reversible so that the compression is deactivated. The isolation mechanisms 58 may be activated by any known means, such as hydraulically (by applied pressure or pressure pulses), electrically, acoustically, or

electromagnetically. Any hydraulic signals can be sent through the tube 34.

Each isolation mechanism 58 may comprise an elastomeric cone-shaped gland 60 having one or more openings 62 for receiving the communication line therethrough. In this particular example, each gland 60 has openings for receiving one or more communication lines 36 (such as optical fibers 64) therethrough. The gland 60 is compressed inside a compression fitting to form a pressure seal that prevents the transfer of fluid and pressure from another zone of tube 34.

The communication line, e.g. optical fiber(s) 64, is connected to one or more sensors 66 deployed in isolated tube zone 56. In one exemplary embodiment, sensor 66 is a fiber sensor disposed within tube 34 in communication with optical fiber 64. The fiber sensor measures a given physical or chemical property and may comprise a temperature sensor, a distributed temperature sensor, a pressure sensor, an acoustic energy sensor, an electric current sensor, a magnetic field sensor, an electric field sensor, a flow sensor, a chemical property sensor or a variety of combinations thereof. In fact, the illustrated optical fiber 64 can represent multiple optical fibers, and sensor 66 can represent multiple sensors of various types coupled

to a corresponding optical fiber. Other types of sensors include electrical, electrical MEMS, or fiber powered MEMS. In the example illustrated, isolation mechanisms 58 function as miniature fiber optic packers.

In general, the sensor 66 is selectively communicated with the environment external to the tube 34 in order to sense the desired parameter. Such communication can be either direct or through intermediary devices such as bellows or pistons.

In an alternate embodiment, illustrated in Figure 4, another type of fiber optic packer 68 is illustrated. Fiber optic packer 68 is formed as part of the wall of tube 34. The fiber optic packer 68 can be expanded or moved through the center of tube 34 to seal optical fibers 64 against the interior surface of the tube wall, as illustrated in Figure 4. Reference number 68A shows the packer in its unexpanded state, and reference number 68B shows the packer in its expanded state. Reference number 64A shows the optical fiber in its unsealed state, and reference number 64B shows the optical fiber in its sealed state.

By increasing the length of packer 68 or other isolation mechanism, the strain on communication line 36 can

be reduced. This is particularly beneficial with communication lines, such as optical fibers, that are more susceptible to breakage. Also, fiber optic packer 68 can be designed as a reversible packer, such that the packer can be contracted or moved away from optical fiber 64 to permit retrieval and replacement of communication line 36 and any attached sensors. Such retrieval and replacement can be achieved by pumping the old line 36 out of tube 34 and pumping the new line 36 into the tube 34.

In another embodiment, the isolation of zones in control line tube 34 can be accomplished inside of a downhole device 70, such as a packer, instrumented sub, or any other downhole tool, such as valves, crossovers, etc. (See Figures 5, 6 and 7). Packer or instrumented sub 70 is designed to receive primary tubing 40 and control line tube 34 therethrough. Device 70 also is designed to enable the isolation of tube 34 at a pair of compression sections 72 to isolate an internal zone 74 from fluid and pressure influences external to zone 74.

In one embodiment, a pair of pinch mechanisms 76 are activated to provide the isolation. Pinch mechanisms 76 can comprise the embodiments of isolation mechanism 58, as previously described.

In one embodiment, the pinch mechanisms 76 are moved against tube 34 at each compression section 72 to isolate internal zone 74. By way of example, , compression sections 72 may be formed of a resilient, elastomeric material to facilitate compression and sealing of internal zone 74.

As illustrated best in Figures 6 and 7, the sensor 66 can comprise a fiber sensor 78 positioned along communication line 36 (e.g. optical fiber 64) within internal zone 74. Sensor 66, such as fiber sensor 78 may be exposed to a desired parameter, e.g. pressure, external to tube 34 via a port 80. Port 80 can be designed to provide direct exposure to the environment external to tube 34, or other devices can be employed intermediate port 80 and the surrounding environment. For example, port 80 and sensor 66, such as fiber sensor 78, may be placed in communication with the surrounding environment via a valve 82 and a bellows 84.

In this embodiment, valve 82 is closed when compression sections 72 are open, as illustrated in Figure 6. However, when compression sections 72 are sealed, as illustrated in Figure 7, valve 82 is opened to expose sensor 66 (such as fiber sensor 78) to external pressures. Thus, sensor 66

(such as fiber sensor 78) is able to determine, in this example, the external pressure and provide appropriate output along communication line 36. Bellows 84 permits exposure of sensor 66 (such as fiber sensor 78) to external pressure without exposing the sensor to the actual wellbore fluids.

In another embodiment, illustrated in Figures 8, 9 and 10, a packer 86 including slips 85 and sealing element 87 is deployed within wellbore casing 28 about primary tubing 40 and tube 34 (with a communication line therein). A zone 88 within tube 34 is isolated by a pair of connectors 90, such as dry mate connectors with integral bulkheads. Connectors 90 are deployed at the upper and lower regions of packer 86 to isolate zone 88 and one or more sensors 92.

By way of example, three sensors may be deployed in tube 34 within zone 88 in order to measure a parameter of interest at various points. The sensed parameter is measured at locations above packer 86, within primary tubing 40 and below packer 86 via ports 94, 96 and 98, respectively. Each of the sensors 92 is selectively isolated from the other sensors 92 by way of isolation mechanisms 99, such as the isolation mechanisms previously

disclosed (See Figure 9). Isolation mechanisms 99 cooperate with, for example, connectors 90 to isolate separate zones within zone 88. In this example, separate zones are established about each sensor 92. However, the number of zones and the sensors disposed within each separate zone can be adjusted according to the specific application. Each of the sensors 92 is coupled to communication line 36 which, in this embodiment, can comprise one or more optical fibers or electrical cable conductors. As with the embodiments discussed above, sensors 92 may comprise a variety of sensor types (measuring a physical or chemical property), such as fiber sensors disposed within tube 34. Exemplary sensors comprise temperature sensors, distributed temperature sensors, pressure sensors, acoustic energy sensors, electric current sensors, magnetic field sensors, electric field sensors, flow sensors, chemical property sensors, fluid sampling sensors, etc. that can be, for example, optical or electrical, e.g. micro-electro-mechanical systems (MEMS) or fiber powered MEMS. Additionally, a variety of combinations of such sensors can be utilized to determine various combinations of parameters.

Sensors 92, ports 94, 96, 98, and the associated isolation mechanisms may be used in tools other than a

packer, such as valves, pumps, crossovers, etc. A packer is shown only for purposes of illustration.

Although three ports 94, 96, and 98 are shown in packer 86, it is understood that any number of ports may be included in the relevant device, each port providing communication between a sensor and an area where a parameter needs to be sensed.

In one embodiment, the packer 86 and the isolation mechanisms can be activated or deactivated (if reversible) using the same signal. For instance, applied pressure or pressure pulse telemetry may be used to send a signal to the packer 86 (such as even sending the signal through the tube 34), which results in the setting of the slips 85 and sealing element 87 as well as in the activation of the isolation mechanisms to provide the proper tube isolation. Other telemetry techniques may also be used.

In a further embodiment, the packer 86 includes bulkheads 100, 102, 104, 106 (each incorporating line feedthroughs 108, 110, 112 and 114, respectively) permanently sealing against the communication line 36 so as to isolate the sensor regions in the packer 86. Each sensor

92 can then sense the parameter of interest without being affected by the environment in the other sensor regions.

It should be understood that the foregoing description is of exemplary embodiments of this invention, and that the invention is not limited to the specific forms shown. For example, the sensor isolation system can be utilized in a variety of environments and in combination with a variety of completions or other downhole devices; the types and combinations of sensors can vary from one application to another; the type and number of communication lines can vary; the size and positioning of the sensors can be adjusted depending on the application; and the tube isolation mechanisms can be utilized independently or in combination with other wellbore isolation devices, such as packers, to isolate individual or multiple wellbore zones. These and other modifications may be made in the design and arrangement of the elements without departing from the scope of the invention as expressed in the appended claims.

CLAIMS

What is claimed is:

1. A system for sensing desired parameters in a wellbore environment, comprising:

a tubing through which a desired fluid is produced;

a downhole device disposed about the tubing; and

a secondary tubing having a smaller diameter than the tubing and an internal communication line, the secondary tubing being coupled to the downhole device, wherein the secondary tubing comprises a plurality of isolated regions through which the internal communication line extends.

2. The system as recited in claim 1, wherein the downhole device comprises a packer.

3. The system as recited in claim 1, further comprising a plurality of sensors coupled to the internal

communication line, the sensors each measuring a different type of parameter.

4. The system as recited in claim 3, wherein the internal communication line comprises an optical filter.

5. The system as recited in claim 3, wherein the internal communication line comprises a plurality of optical fibers.

6. The system as recited in claim 1, further comprising at least one sensor coupled to the communication line and disposed in at least one of the plurality of isolated regions.

7. The system as recited in claim 6, wherein the at least one sensor comprises a pressure sensor.

8. The system as recited in claim 6, wherein the at least one sensor comprises a flow sensor.

9. The system as recited in claim 6, wherein the at least one sensor comprises a fluid sampling sensor.

10. The system as recited in claim 6, wherein the at least one sensor comprises a MEMS sensor.

11. The system as recited in claim 1, wherein the plurality of isolated regions are formed by a plurality of permanent bulkheads.

12. The system as recited in claim 1, wherein the plurality of isolated regions are formed by reversible fiber optic packers disposed along a wall of the secondary tubing.

13. The system as recited in claim 1, wherein the plurality of isolated regions are formed by flexible walls that can be selectively squeezed to isolate regions of the secondary tubing.

14. A system for sensing desired parameters in a wellbore environment, comprising:

a control line tube having a sealable wall;

a communication line disposed within the control line tube; and

a sensor deployed in the control line tube in communication with the communication line, the sensor being disposed in a zone isolated within the control line tube by sealing the sealable wall at a plurality of locations.

15. The system as recited in claim 14, wherein the communication line comprises an optical fiber.

16. The system as recited in claim 14, wherein the communication line comprises a plurality of optical fibers.

17. The system as recited in claim 15, wherein the control line tube is formed of stainless steel and flexible regions.

18. The system as recited in claim 14, wherein the control line is less than 0.50 inches in diameter.

19. The system as recited in claim 14, wherein the sensor comprises a pressure sensor.

20. The system as recited in claim 16, wherein the sensor comprises a plurality of sensors coupled to the plurality of optical fibers.

21. The system as recited in claim 20, wherein the plurality of sensors are configured to sense a plurality of different parameters.

22. The system as recited in claim 14, wherein the zone is formed by squeezing together the sealable wall.

23. A method of evaluating conditions in a wellbore, comprising:

locating a tubing in a wellbore;

deploying a communication line within the tubing for communication with a sensor;

placing the sensor in a zone within the tubing; and

isolating the zone from tube pressures outside the zone by collapsing the tubing at one or more selected regions.

24. The method as recited in claim 23, wherein deploying comprises deploying an optical fiber.

25. The method as recited in claim 23, further comprising running a primary tubing into the wellbore.

26. The method as recited in claim 25, further comprising lining the wellbore with a casing.

27. The method as recited in claim 26, wherein locating comprises locating the tubing between the primary tubing and the casing.

28. The method as recited in claim 26, wherein locating comprises locating the tubing external to the casing.

29. The method as recited in claim 23, wherein deploying comprises coupling the communication line with a fiber sensor.

30. The method as recited in claim 23, wherein deploying comprises coupling the communication line with a pressure sensor.

31. The method as recited in claim 23, wherein deploying comprises coupling the communication line with a MEMS sensor.

32. The method as recited in claim 23, wherein placing comprises placing a plurality of sensors within the tubing to sense a plurality of parameters.

33. The method as recited in claim 23, wherein isolating comprises squeezing the tubing at a plurality of isolation regions.

34. The method as recited in claim 23, wherein isolating comprises plugging the tubing at one or more isolation regions.

35. The method as recited in claim 23, wherein deploying comprises deploying a plurality of optical fibers connected to sensors designed to sense more than one wellbore parameter.

36. A system for evaluating conditions in a wellbore, comprising:

means for deploying a communication line within a wellbore;

means for isolating a pressure zone along the communication line by sealing a tubing about the communication line; and

means for incorporating a sensing capability with the communication line.

37. The system as recited in claim 36, wherein the means for deploying comprises a tubing.

38. The system as recited in claim 37, wherein the means for isolating comprises an isolation member to sealingly close the interior of the tubing.

39. The system as recited in claim 38, wherein the means for incorporating comprises a fiber sensor.

40. A method for sensing one or more parameters within a plurality of zones along a wellbore, comprising:

isolating a plurality of zones within a tube by forming sealed regions along an interior of the tube;

placing an optical fiber within the tube; and

sensing the one or more parameters via sensors disposed within the plurality of zones along the optical fiber.

41. The method as recited in claim 40, wherein isolating comprises plugging the tube at the sealed regions.

42. The method as recited in claim 40, wherein isolating comprises squeezing the tube at the sealed regions.

43. The method as recited in claim 40, wherein sensing comprises sensing pressure.

44. The method as recited in claim 40, wherein sensing comprises sensing a plurality of different parameters.

45. The method as recited in claim 40, wherein isolating comprises isolating regions within a downhole tool.

46. The method as recited in claim 40, wherein isolating comprises isolating regions within a packer.

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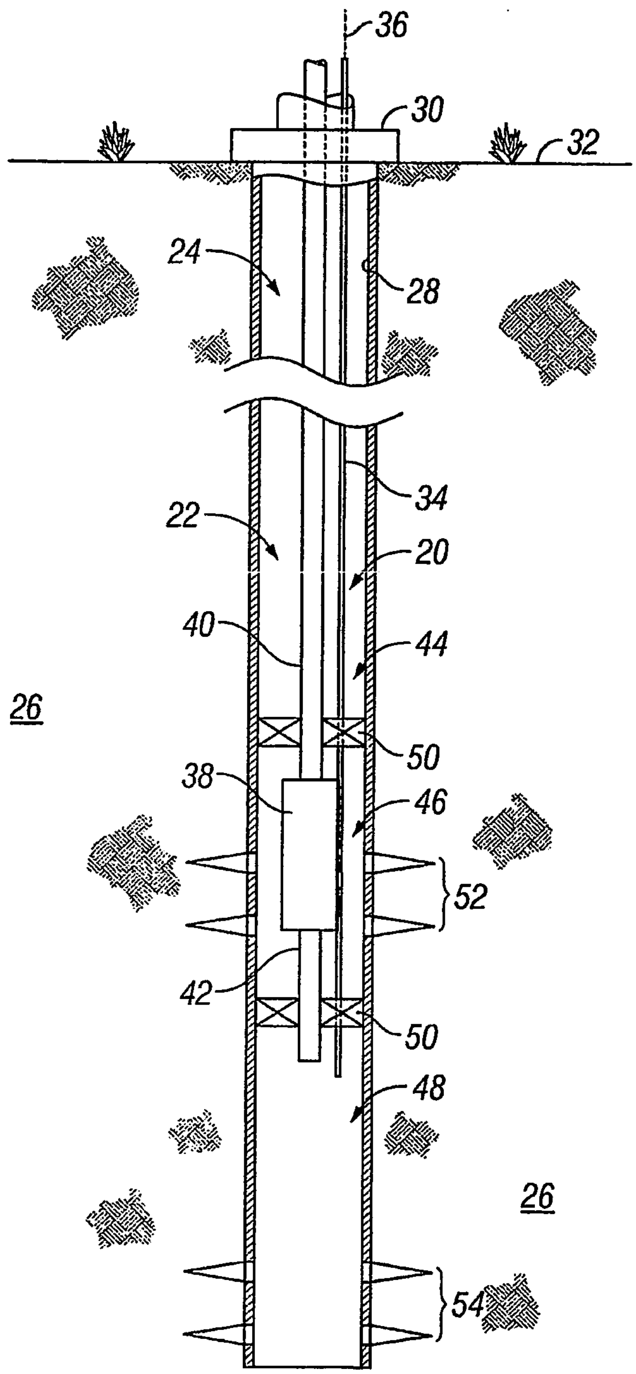

FIG. 1

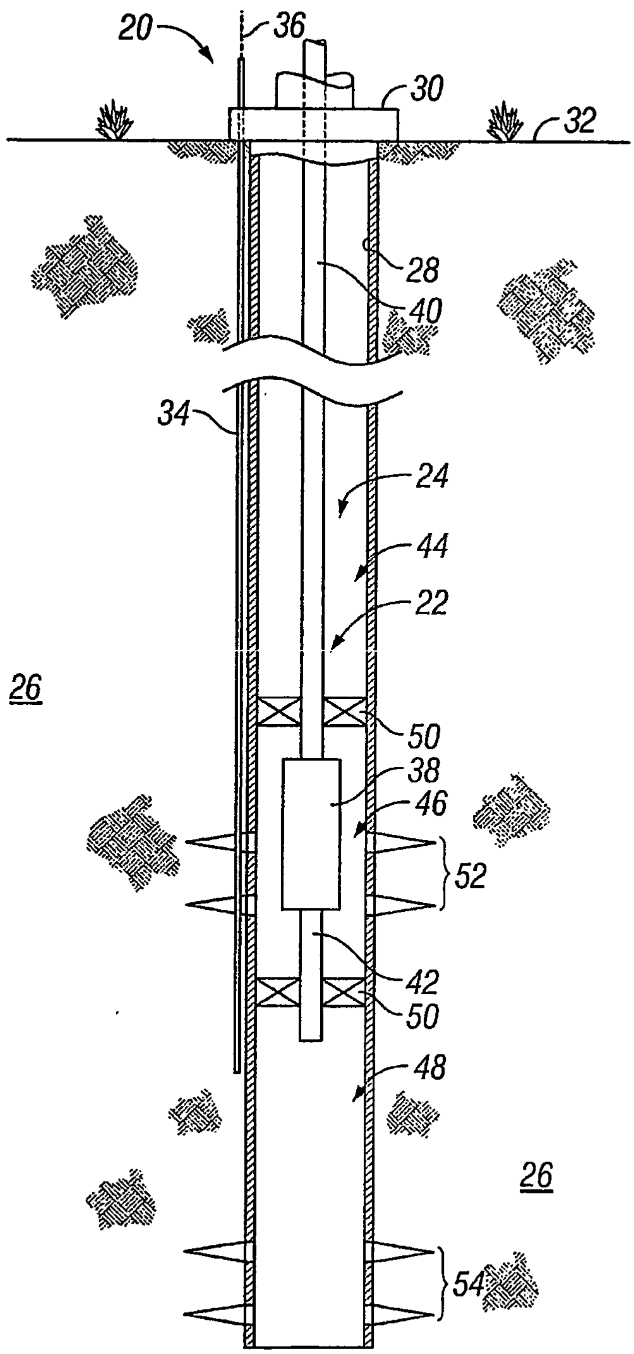

FIG. 2

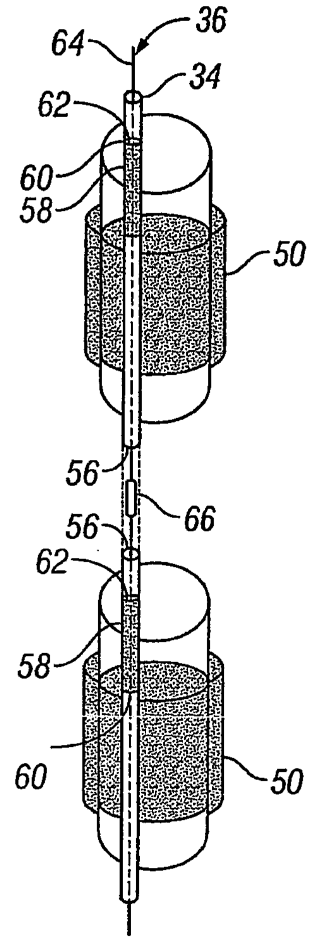

FIG. 3

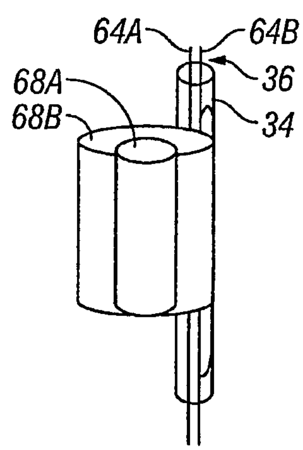

FIG. 4

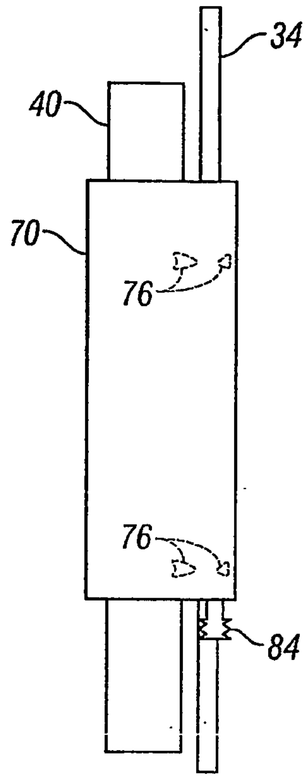

FIG. 5

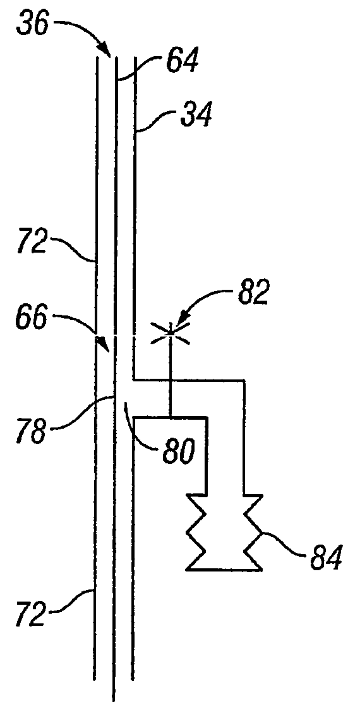

FIG. 6

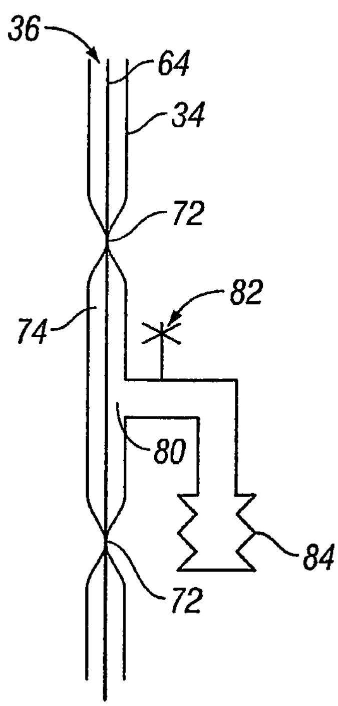

FIG. 7

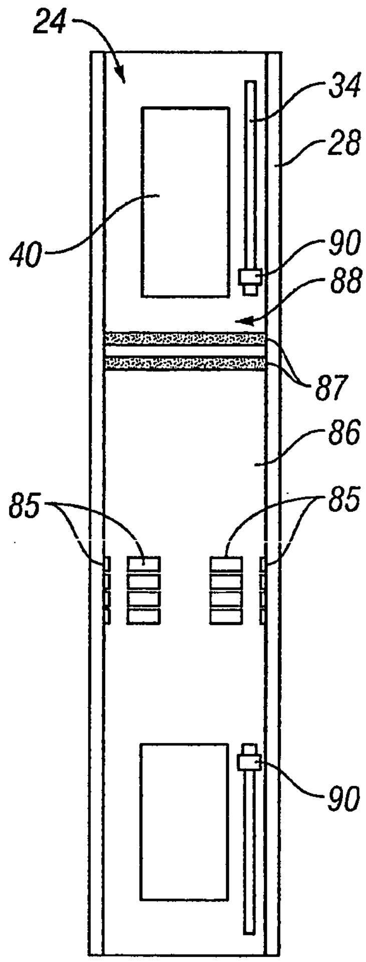

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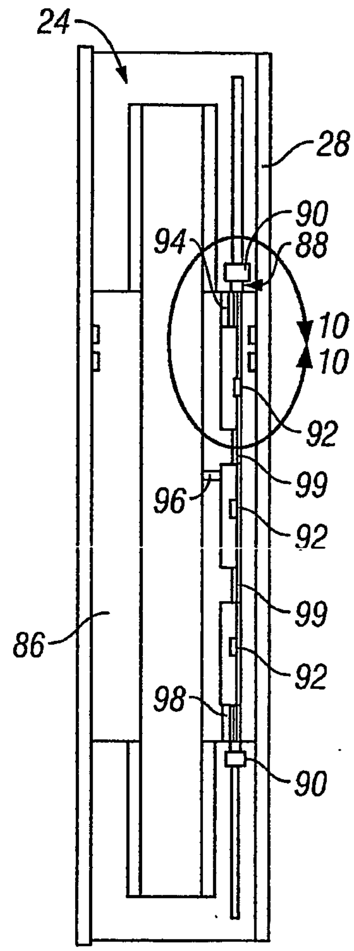
FIG. 8



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88
10
10
92
99
96
92
99
86
92
98
90

FIG. 9

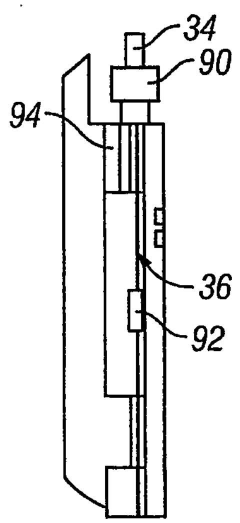
34
90
94
36
92

FIG. 10

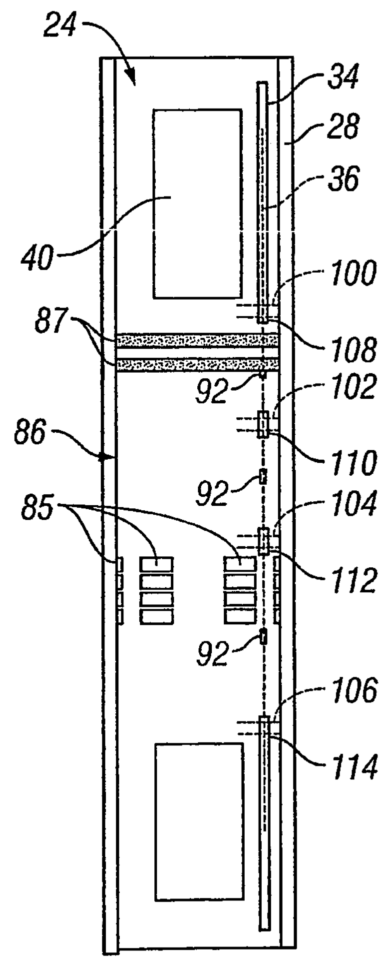
24
34
28
36
40
100
87
108
92
102
86
110
92
85
104
112
92
106
114

FIG. 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/04106

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B47/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/109080 A1 (LEGGETT NIGEL ET AL) 15 August 2002 (2002-08-15) paragraphs ‘0055!-‘0057!; claims 1-59; figures 3,4 ---	1-12, 14-21, 23-32, 34-41, 43-46
X	US 6 257 332 B1 (VIDRINE WILLIAM L ET AL) 10 July 2001 (2001-07-10) claims 1-66; figures 1,1A,3,4 ---	1-12, 14-21, 23-32, 34-41, 43-46
A	US 6 009 216 A (PRUETT PHILLIP EDMUND ET AL) 28 December 1999 (1999-12-28) abstract; figure 1 ----	1,14,23, 36,40

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 January 2004	20/01/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Tompouloglou, C

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 03/04106

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